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BIOMEDICAL APPLICATIONS OF NASA SCIENCE AND TECHNOLOGY

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PREFACE

This report covers the 15 June 1968 to 14 June 1969 activities of the NASA Biomedical Application Team at the Research Triangle Institute. These activities were performed in accomplishing Tasks A through F, Statement of Work, NASA Contract No. NSR-34-004-056. Accomplishment of Task G, Supplementary Efforts, is reported separately. This work was performed in the Engineering and Environmental Sciences Division of the Research Triangle Institute under the technical direction of Dr. James N. Brown, Jr. Full-time members of the team and other RTI staff members who participated in the project are Dr. F. T. Wooten, Mr. Ernest Harrison, Mrs. Sandra K. Burt, Dr. D. F. Palmer, Mr. J. B. Tommerdahl, and Mr. R. L. Beadles.

Medical research consultants who contributed significantly to the project are Dr. E. A. Johnson, Professor of Cardiac Pharmacology, Duke University Medical Center, Durham, North Carolina and Dr. G. S. Malindzak, Jr., Associate Professor of Physiology, Wake Forest University, Bowman Gray School of Medicine, Winston-Salem, North Carolina.

ABSTRACT

This report presents the results and an analysis of the activities of the NASA Biomedical Application Team at the Research Triangle Institute. This experimental program in technology transfer was supported by NASA Contract No. NSR-34-004-056 for the reporting period 15 June 1968 to 14 June 1969. The RTI Biomedical Application Team is a multidisciplinary team of scientists and engineers acting as an information and technology interface between NASA and individuals, institutions, and agencies involved in biomedical research and clinical medicine. At present, the RTI Biomedical Application Team is staffed by: J. N. Brown, Electrical Engineer; F. T. Wooten, Electrical Engineer; Ernest Harrison, Physicist and Materials Scientist; and Sandra Burt, Information Specialist. Additionally, the team draws upon the capability of other members of the RTI staff as needed.

Seven medical institutions are presently participating in the RTI Biomedical Application Team program: Duke University Medical Center, Durham, North Carolina; the Medical School of the University of North Carolina, Chapel Hill, North Carolina; the University of North Carolina Dental School and Dental Research Center, Chapel Hill, North Carolina; the Bowman Gray School of Medicine, Winston-Salem, North Carolina; the North Carolina State University, Raleigh, North Carolina; the Veteran's Administration Hospital, Durham, North Carolina; and the Institute of Rehabilitation Medicine of New York University Medical Center, New York, New York.

The accomplishments of the RTI Biomedical Application Team during the last three years can be summarized as follows: Since 15 June 1966, the team has worked on 225 specific technology-related biomedical problems. Eighty of this total number of problems are at present active, and solutions are being sought. A total of 41 transfers of technology have been accomplished during this period. During the preceding contract year, 53 new problems were accepted for investigation, and 17 technology transfers were accomplished. During this period 24 computerized information searches were performed, and one biomedical problem abstract was submitted to NASA's Technology Utilization Division for dissemination to NASA centers.

The types of technology transfers accomplished during the preceding contract year ranged from purely information transfers to devices, instrumentation, and implantable prostheses. NASA-developed fluid control technology was adapted to the design and fabrication of a prototype prosthetic urethral valve. Information on ultrasonic nondestructive testing was transferred to a research program in diagnostic ultrasonics. Ferrite pressure transducers developed for measuring pressures in materials used by NASA are being adapted to the measurement of blood flow in the human body. An additional transfer of interest was the application of low-velocity flight balance instrumentation developed in the Russian space program to monitoring the flight of birds in a research project at Duke University.

An analysis of the team's operations indicates that technology transfer programs are made more effective and efficient as problem selection and screening receive greater emphasis. Both the capabilities of the problem originator and the facilities available to him to adapt and apply technology are very important factors in problem selection. Also, the ability to define a problem as a single and specific technological requirement is an important selection factor. Finally, and most importantly, analysis shows clearly that aerospace technology can be applied beneficially in the biomedical field, and the success of the Biomedical Application Team Program has not been limited by an inability to identify aerospace technology applicable to specific biomedical problems.

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1.0 INTRODUCTION AND SUMMARY

The Technology Utilization Division of the National Aeronautics and Space Administration is experiencing success in transferring the scientific and technological results of the nation's aerospace activities to applications in non-aerospace related national programs. [1] The transfer of science and technology to the biomedical field and the study of the process by which this transfer occurs is one of the major endeavors in NASA's Technology Utilization Program. Systematic problems are encountered in transferring technology to problems and needs existing in the biomedical field. These problems are a result of differences in languages, methodologies, and environments encountered in the physical-engineering and life sciences.

In other to create a mechanism for and to facilitate the transfer of scientific and technological information to clinicians and medical investigators, the National Aeronautics and Space Administration is presently sponsoring three multidisciplinary Biomedical Application Teams. These three teams are located at the Research Triangle Institute, Research Triangle Park, North Carolina; the Midwest Research Institute, St. Louis, Missouri; and the Southwest Research Institute, San Antonio, Texas. These three application teams closely coordinate their activities to avoid duplication of effort and to enhance investigation of the technology transfer process.

The objectives of NASA's Biomedical Application Team Program are both experimental and operational. The experimental phase of the program is the study of the technology transfer process and the development of a systematic approach to transferring aerospace technology to applications in medicine and biomedical research. The operational phase of the program is the transfer of specific items of aerospace technology to the biomedical field and the generation of a data base for further study of the transfer process.

The methodology employed by the Biomedical Application Team can be subdivided into four major phases of action: identification and specification of the problem, identification of relevant information or technology, evaluation of potentially applicable information or technology, and documentation of specific applications or technology transfers and the manner in which these technology transfers were accomplished.

The first phase of the transfer process, identification and specification of the problem, is the initiation of discussions between members of the team and medical investigators at participating medical institutions. In these meetings, team members obtain an understanding of the problems and requirements posed by the medical investigators and of the way these problems are affecting the progress of medical research or hindering patient treatment and care. Following these discussions and preliminary literature research, the team identifies specific technology-related problems and prepares biomedical problem abstracts on each specific problem. These biomedical problem abstracts describe a single problem in a concise manner using functional and nondisciplinary terminology. They also describe the significance of the problem and the benefits which would likely be realized if a solution can be found.

The second phase in the transfer process, the identification of relevant information and technology, involves two approaches to obtaining information. The first approach is a computerized information search of NASA's aerospace information bank. This information bank consists of the entries in the Scientific and Technical Aerospace Reports and the International Aerospace Abstracts. These computer information searches are performed collaboratively by members of the application team and applications engineers at NASA Regional Dissemination Centers, such as the North Carolina Science and Technology Research Center located in the Research Triangle Park, North Carolina. In the second approach, biomedical problem abstracts are disseminated through the Technology Utilization Division of NASA to the NASA Research Centers to solicit, from individual engineers and scientists, assistance in solving problems.

The third step in the transfer process involves an evaluation of information which appears to be relevant to the solution for a specific problem. This evaluation is performed both by members of the team as well as the problem originator. If information is identified which appears to offer a solution to a specific problem, the team encourages and, to a certain extent, assists the investigator in applying this information in his research project.

The final phase of activity involves the complete and detailed documentation of specific problems, the technology or information which was applied and how it was applied, and a description of how the relevant information was identified. Documentation is required both for further study of the transfer process as well as for wide dissemination of the information throughout the medical community.

Seven medical schools and institutions are presently participating in the RTI Biomedical Application Team program. They are the Duke University Medical Center, Durham, North Carolina; the University of North Carolina Medical School, Chapel Hill, North Carolina; the University of North Carolina Dental School and Dental Research Center, Chapel Hill, North Carolina; the North Carolina State University, Raleigh, North Carolina; the Wake Forest University Bowman Gray School of Medicine, Winston-Salem, North Carolina; the Veteran's Administration Hospital, Durham, North Carolina; and the Institute of Rehabilitation Medicine of New York University, New York, New York.

Discussions of the activities of the RTI Biomedical Application Team are presented in the remaining sections of this report. These discussions include a summary and analysis of technology transfers accomplished during the preceding 36-month and 12-month periods, a summary and analysis of the status of active problems, evaluations of computer searches performed during the reporting period, a discussion of application engineering which has resulted from the team's activities, conclusions related to the technology transfer process, and recommendations for future activities of the RTI Biomedical Application Team.

2.0 TECHNOLOGY TRANSFERS

During the past three years, the RTI Biomedical Application Team has accomplished 41 transfers of aerospace technology to problems in the biomedical field. Of these, 24 occurred during the period 15 June 1966 to 14 June 1968 and they are documented in the Final Reports on that period of time. [2,3] Of the 17 transfers completed during the preceding 12-month reporting period, 14 have been documented in the three Quarterly Reports published during that contract year - i.e., 15 June 1968 to 14 June 1969. [4,5,6] The remaining three transfers are documented in Transfer Reports which appear in Section 2.2.

2.1 Summary and Analysis of Technology Transfers

All 41 transfers which have been accomplished by the RTI Biomedical Application Team are listed in Table 1. They are subdivided, in the table, according to the contract year in which they occurred. The problem code and number preceding each problem and transfer title identifies the medical institution involved and the order in which the problems were specified at that institution. The problem code should be interpreted as follows:

DU - Duke University Medical Center

HSS - Hospital for Special Surgery

NCSU - North Carolina State University

UNC - University of North Carolina

UNCD - University of North Carolina Dental School

WF - Wake Forest University

MISC - Miscellaneous

Table 1

Transfers

15 June 1966 to 14 June 1967

Problem No.	Title
DU-6	Correction for Latency in Vidicons.
WF-10	Theoretical Treatments of Holography Which Discuss Aberrations and Distortions.

15 June 1967 to 14 June 1968

Problem No.	Title
DU-1	Techniques for Calculating Left Ventricular Volume from Biplane Cineradiographs.
DU-23	Methods of Improving Resolution and General Quality of Electron Micrographs to Obtain More Information on the Structure of Cell Membranes.
DU-26	Cardiac Artery Constrictor.
DU-28	Fluid Dynamics of Sucrose Gap Chambers.
DU-29	Methods of Fabricating Sucrose Gaps.
HSS-1	A Method of Measuring and Telemetering the Force Applied to Broken Bone Joints by Implanted Braces.
NCSU-2	Information on Environmental Capsules for Opossums.
UNC-2	Information Related to Bone Growth and Resorption.
UNC-9	Analysis of Electrophoretic Scan Data.
UNC-12	Low Temperature Lubricant for Microtomes.

Table 1

Transfers (Continued).

Problem No.	Title
UNC-13	Methods of Reinforcing Thermo-plastic Braces and Casts.
UNCD-11	A Means of Sampling Bacteria in the Nasal and Sinus Cavities Which is Simpler and Less Unpleasant to Patients.
UNCD-13	An Economical Dry Heat Sterilization Apparatus.
UNCD-14	Design of "Clean" Rooms,Especially "Laminar Flow" Rooms.
WF-6	Seven-Channel,Portable,Battery-Operated Tape Recorder.
WF-7	Method of Correcting for Spherical Aberration in Ultrasonic Holograms.
WF-13	Radiation Detector for In Vivo Measurement of Absorbed Dose.
WF-30	An Improved Blood Vessel Constrictor.
WF-39	Information needed on the Physiological Effects (Radiation Damage, etc.) Arising from Use of Short-lived Radio Isotopes in Treatment and Autoradiography.
WF-45	Sensitivity of Animal Cells to Radiation as a Function of Amount of Oxygen Present in Tissue and as a Function of Radiation Dose Rate.
WF-50	Application of Time-Series Analysis to Computer Processing of Biomedical Data.

15 June 1968 to 14 June 1969

Problem No.	Title
DU-20	Multi-electrode Needles.
DU-24	A Signal Conditioning and Multiplexing System for Multiple Electrode EKG Patient Monitoring.
DU-37	Localized Cooling of Heart Muscle.

Table 1

Transfers (Continued).

Problem No.	Title
MISC-1	Biomedical Tape Recorder.
NCSU-5	Oxygen Content of Ichthyological Ovarian Fluid.
UNC-48	An Improved EMG Electrode for Hand Therapy.
UNC-49	A Manipulator for Therapy in Abductor Transfer Cases.
WF-3	Prosthetic Valve for Urinary Tract.
WF-37	An Implantable Valve Which Can Be Remotely Opened and Closed From Outside the Body.
WF-52	Methods of Triggering from a Fixed Reference Point on the EKG Waveform.
WF-54	An Improved Sensing System for Indicator Dilution Studies.
WF-55	A Simple Means of Sensing Whether Respirator is Actually Performing the Respiratory Function on Humans.
WF-58	Information on Ultrasonics.
WF-63	A Low Cost, Swallowable, pH Sensing Telemetering Capsule.
DU-40	Differential Pressure Transducer for Cardiac Catheter.
DU-43	Small Low-Velocity Flight Balance.
NCSU-4	Telemetry from Wood Ducks in Natural Environment.
UNC-51	An Improved Electrode for Electro-Diagnosis.

The code MISC is used for problems originated by researchers who are not located at one of the institutions formally participating in the Biomedical Application Team Program.

As pointed out in the Introduction, one of the two major objectives of the Biomedical Application Team Program is the development of an effective and efficient methodology for transferring technology to the biomedical field. In attempting to reach this goal, the successes in transferring technology must be continually analyzed in order to determine what changes in the team's approach can increase the flow of technology resulting from the nation's space program to biomedical applications. In the following paragraphs, characteristics of the transfers listed in Table 1 and the ways in which these transfers were achieved are discussed from the standpoint of Biomedical Application Team methodology.

Table 2 lists the categories of transfers in regard to what type of information was sought by the team. In some cases the researcher asked for a particular category of information but in order to broaden the base of information, the team looked for a different category. For example, one researcher asked the team to look for an instrument for digitizing the output of a pantograph used to trace the outline of the heart on a cineradiograph. This digital data was to be used to calculate heart volume. Instead, the team looked for general methods of measuring heart volume using cineradiographs and, as a result, disclosed a new approach to the problem of heart volume measurement that was a significant improvement over existing methods.

Table 2

Types of Transfers and Problems.

Category		Problems		Transfers	
		Number	Percent	Number	Percent
I.	Approach	112	43.1	13	27
II.	Hardware	94	36.1	25	52
	a. Optical			2	
	b. Fluidic			5	
	c. Electronic			18	
	d. Mechanical			8	
	e. Sonic			1	
	f. Thermal			2	
	g. Magnetic			0	
	h. Chemical			3	
III.	Materials Technology	26	10	3	6.2
IV.	Experimental Data	28	10.8	7	14.8
		260		48	

In Table 2 note that the total of the transfer column is 48 although Table 1 states that 41 transfers have occurred. This is because 7 transfers are listed in two categories. This also is the reason why the total of the problem column is 260 when in fact only 225 problems have been considered by the team. Thirty-five of the problems can reasonably be considered in two categories.

These results demonstrate that the largest number of transfers are of the hardware category. Note that 52% of the <u>transfers</u> are of the hardware category while only 36.1% of the <u>problems</u> are of the hardware categories. Thus, the hardware category contains not only a majority of the number of transfers but also is the category with the highest percentage of success.

The second most significant category is that of approach which consists of 27% of the transfers and 43% of the problems. This category has a lower percentage success than does the hardware category. Thus,it is clear that the hardware category is most successful both from the standpoints of probability of solution and number of problems. This information should be used in problem selection to improve the team efficiency.

There are a number of approaches to obtaining solutions as discussed in the Introduction,and the knowledge of which sources are most productive will improve the team efficiency. Table 3 lists the sources of solutions. Category A refers to the responses received from the NASA field centers from problem abstracts circulated by the Technology Utilization Officers. The team circulates quarterly reports to the NASA field centers and the transfers of Category B originated from suggestions generated by the field centers after reading problem descriptions in these reports. Computer searches of the aerospace data bank comprise the solutions of Category C, and manual searches by the team comprise Category D. Team experience including that gained from previous problems comprises Category E. Some solutions are found in the commercial literature,and this is the Category F. As with the previous table the total (47) of the transfer column exceeds the actual number (41) of transfers because some transfers reasonably fall into two categories.

Table 3

Sources of Solution.

	Source	Number of Transfers	Percent of Transfers
A.	Problem Abstract	5	10.6
B.	Report Response	1	2.1
C.	Computer Search	13	27.6
D.	Manual Search	15	31.9
E.	Experience	10	21.2
F.	Commercial	3	6.4
		47	100.0

Note that the primary sources of solutions are the computer search and the manual search. Experience also is a significant source which validates the concept of a multidisciplinary team approach. The fact that only 10.6% of the solutions came from problem abstracts does not mean that the problem abstracts are inefficient. On the contrary, problem abstracts are submitted only after the team has searched for a solution both manually and using the computer. Thus, the problem abstracts are used only on "hard-core" problems, but the team plans to increase the use of problem abstracts in the future to more effectively utilize this valuable tool of the transfer process. A further source of solutions, commercial literature, is appropriately small.

Another significant fact regarding the transfer process can be seen by observing the number of transfers by time of the year as shown in Table 4. The first quarter begins on June 15 and covers the summer period. Note that the number of transfers is low; this probably can be attributed to the fact that many of the researchers are away during the summer. In addition, those researchers with clinical duties are unusually busy because of the reduction in staff caused by vacations. The end result is a low level of team activity at the medical schools,and the team spends much time working on existing problems. The second quarter begins with the academic year,and many researchers are involved in new classroom duties as well as preparing proposals for the November NIH deadline. By the third quarter the team activities are most fruitful although some reduction is seen by the fourth quarter. Knowledge of this seasonal variation enables the team to concentrate on new problems when the researchers are available and to work on existing problems when researchers are unavailable.

Table 4

The Number of Transfers as a Function of Contract Quarter for the Three Contract Years.

Contract Year	Contract Quarter 1	2	3	4
1966-1967	0	1	3	0
1967-1968	0	4	8	8
1968-1969	4	1	9	3
TOTAL	4	6	20	11

During the three years of team activity the experimental process has caused an improvement in efficiency. This can be seen in Table 5 which shows the transfers and new problems by contract year. Note that the ratio of transfers to new problems has improved because the team has learned to select problems with a greater probability of success, as well as learned how to solve problems in a more efficient manner. Continued emphasis on the experimental approach will undoubtedly improve the team efficiency still further.

Table 5

Number of Transfers and New Problems as a Function of Contract Year. Note the Improving Ratio of Transfers to New Problems.

Contract Year	Transfers	New Problems
1966-1967	4	107
1967-1968	20	68
1968-1969	17	53

Another area of interest concerns the transfers as a function of user institution. Table 6 summarizes this information as well as the number of problems. Both numbers are needed because more transfers will obviously occur where more activity has occurred. Note that most of the transfers have occurred at Wake Forest University and Duke University. This can be attributed to the quality of the consultant at each school as well as to a continuity of effort. These two factors are related because a good consultant will contribute to a uniform activity. At both Wake Forest University and Duke University the team has had a consultant continuously, and each consultant has a broad experience in bioengineering. The University of North Carolina is an example of the opposite situation,and as a result the success has been lower. In the other eight schools listed in Table 6

Table 6

Problem and Transfer Summary for Each User Institution.

School	Number of Problems	Number of Transfers	Percent Success
Wake Forest University	67	15	21.7
Duke University	49	11	22.0
University of North Carolina	52	7	13.2
North Carolina State University	7	3	42.8
University of North Carolina Dental School	27	3	11.1
Institute of Rehabilitation Medicine	10	0	0
Miscellaneous	2	1	50.0
Hospital for Special Surgery	2	1	50.0
Veterans Administration Hospital	3	0	0
Rockefeller University	2	0	0
Monte Fiore Hospital	2	0	0
Albert Einstein Institute	2	0	0

a total of 30 problems have been considered with five transfers resulting, which is a lower percentage success than that obtained at Duke University and Wake Forest University where a major continuous effort has been sustained. This data indicates that team activity is more efficient if concentrated and must be considered as the team expands the number of user institutions. It is clear from the above data that if only a few problems are considered at each school, the efficiency may be lower. Thus, within the limitations of available manpower, the number of schools must be carefully expanded.

2.2 Transfer Reports

As indicated in the preceding, the details of three transfers have not appeared in previous reports and are included here.

DU-40

Differential Pressure Transducer for Cardiac Catheter

Dr. C. Frank Starmer and Dr. J. C. Greenfield,
Duke University Medical Center

Team Member - Dr. F. T. Wooten

Problem Acquired - November 19, 1968
Transfer Made - April 21, 1969
Elapsed Time - 5 months

Description of Problem:

The general subject of heart disease is receiving a major research effort. One method of diagnosis of heart disease is to study the pressure and flow relationship in the arteries. One of the few techniques available for this study is to insert a catheter into the artery and to measure pressure at two points along the catheter. From this measurement the flow can be determined. Problems with this technique involve the transducer used for the flow measurement.

The researcher desires a transducer to measure the differential pressure between two points in the human artery from which flow calculations can be made. Improvements desired over existing techniques include higher frequency response, greater resolution, and smaller size.

Description of Solution:

Information from a previous search, #1128, "Blood Flow Meters", was applied to this problem. Although the researchers found this interesting, no specific solution was found.

A manual search of the aerospace commercial literature disclosed a small pressure transducer manufactured by International Technical Industries, Santa Cruz, California. This transducer (Figure 1) had been designed to measure pressure in solids and had never been used in the biomedical field. One of the unique features of the transducer is that it operates on the principle of magnetostriction and can therefore be made extremely small.

Successful Searching Method:

Manual search of aerospace commercial literature.

Benefits to be Derived from Transfer:

This transducer will enable the researchers to improve their measurement techniques on blood flow. This will add to the ever-increasing knowledge of heart function. Heart disease is a major cause (50%) of death in this country.

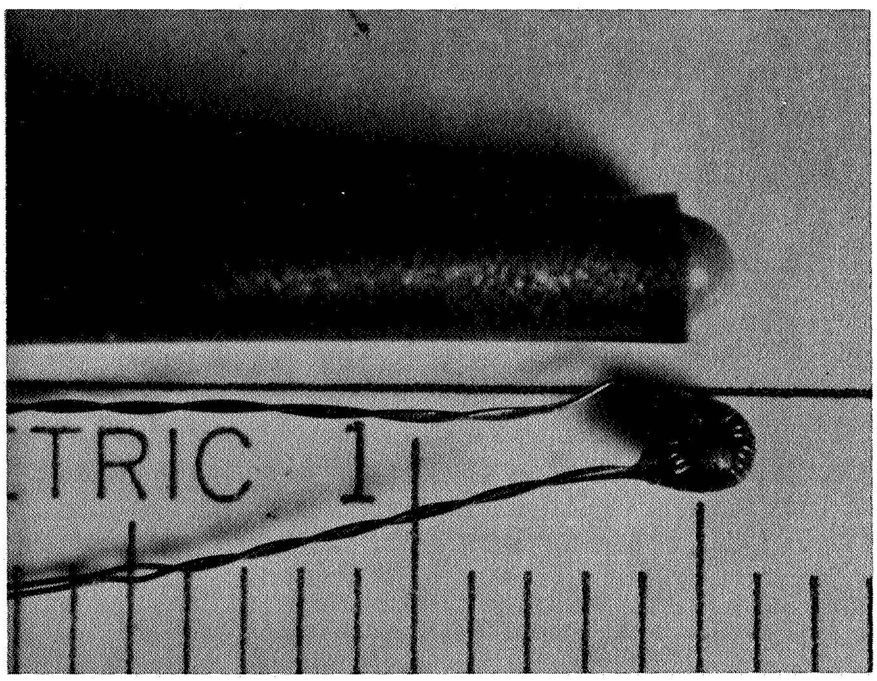

Figure 1. Unmounted and catheter-mounted transducer. Scale division 1 mm.

DU-43

Small Low-Velocity Flight Balance

Dr. V. A. Tucker, Duke University

Team Member - Dr. F. T. Wooten

Problem Acquired - February 7, 1969
Transfer Made - April 23, 1969
Elapsed Time - 2 1/2 months

Description of Problem:

Dr. Tucker has a general interest in avian flight. He is interested in both the aerodynamics and energetics of flight. In order to conduct these studies, he carried out wind tunnel tests on small airfoils that are related in shape to birds. These wind tunnel tests are unusual in regard to size of object (small) and air speed (low). One of the basic tools of wind tunnel testing is a flight balance. It is used to obtain the three moments and three forces acting on an airfoil. One important aspect of using a flight balance is the use of an adequate yaw meter.

Dr. Tucker would like to obtain an improved flight balance and yaw meter.

Description of Solution:

The computer search of the NASA literature, #1604, "Optical Tracking and Flight Balance," disclosed a valuable Russian translation (N67-21381, "Wind Tunnels and Their Instrumentation"). This document cited a yaw meter used for aircraft wind tunnels that could be adapted to the unusual requirements of Dr. Tucker. Previous yaw meters had been sensitive to velocity changes across the tunnel, but the new yaw meter was unaffected by such changes. Dr. Tucker has adapted the idea to his system. The new yaw meter has been built and is functioning properly.

Successful Searching Method:

Computer search of the aerospace literature.

Benefits to be Derived from Transfer:

This improved yaw meter will improve the measurement techniques of the researcher. One important aspect of his research program regards "dynamic soaring" of birds. Some birds are well known for their ability to stay aloft for long periods without wing motion. The use of vertical motions of air or updrafts is well understood. A less understood technique is "dynamic soaring" which means using changes in horizontal wind velocity to obtain lift. This phenomena, if understood, might be applicable to aircraft flight. This transfer will improve the researcher's ability to study this phenomenon.

The researcher stated that the source was invaluable because he would not have been aware of the document otherwise. The researcher felt that the availability of a translated Russian document was also invaluable.

UNC-51

An Improved Electrode for Electro-Diagnosis

Mr. George F. Hamilton, Hand Rehabilitation Center,
University of North Carolina

Team Member - Mr. Ernest Harrison, Jr.

Problem Acquired - April 16, 1969
Transfer Made - May 6, 1969
Elapsed Time - 3 weeks

Description of Problem:

Electro-diagnosis consists of the application of varying frequencies and amplitudes of electrical current while observing the minimal muscular response of a muscle being tested. As a result of the test, one can make a relatively objective evaluation of the degree of neural loss which may exist in a given neuromuscular unit. In the performance of the electro-diagnostic procedure, two variables are obtained relative to nerve-muscle integrity. One is the chronaxie, which is a measure of the amount of time that an electrical current must flow in order to cause a given minimal muscle response. The second is a strength-duration curve, which is a demonstration of the strength of the current as a function of the length of time the current must flow to produce a minimal muscle response. By observing these two variables, one can obtain an indication of the degree of neural depression which may exist in a given muscle.

A hand-held electrode (the electrode will vary with the size of the muscle) is used to deliver electrical shock to a muscle while the operator observes muscle response in the most irritable fibers. The objective of the procedure is to record the variation which exists in electrical strength or electrical pulse duration characteristic as the muscle is stimulated to obtain a constant muscle response.

A significant problem during testing is the maintenance of a given position on the muscle so that the same muscle fibers are observed throughout the examination. If the hand-held electrode is moved at any time during the examination period, it will produce a distortion in the recording process and, as a result, give a less reliable test. A second problem which exists in the use of the hand-held electrode is the variation in the muscle response which will occur with changes in the pressure of the electrode as it is applied to the skin. If the electrode is pressed firmly against the skin, a given response will be obtained. If the pressure is altered in the area tested, a variation in the muscle response will occur. These two problems represent the major deficiencies in the electro-diagnostic procedure and are of such a magnitude that the test, to be properly done, requires the use of two operators. In this technique, one operator is used for recording and manipulating the machine and a second operator to hold the electrode and observe the muscle response. An electrode to eliminate these problems is desired to improve the accuracy of the procedure. It is also desirable that the procedure be simplified to the extent that only one therapist is required to administer the tests.

Description of Solution:

Information from a NASA Technical Note, TN D-3414, "Dry Electrodes for Physiological Monitoring," C. W. Patten, F. B. Ramme, and James Roman, was applied to this problem. A variation of the NASA-developed spray-on electrode was found to be an ideal solution to this problem. The spray-on electrode paste is mixed just as is done when application of the electrode is by spray-on techniques. However, in this case, a small electrode, approximately one-quarter inch in diameter, is painted on with a brush or daubed on with a circular cross-section dowel. The skin is prepared for electrode application by thorough cleansing to remove dead skin tissue and skin oils. Conventional electrode gel is sparingly applied. The skin is then wiped with a clean cloth, and the electrode is applied.

Successful Searching Method:

Knowledge of the "dry electrode" technique was the result of information searching on other biomedical problems, specifically, the first use of dry electrodes made by the Midwest Research Institute in connection with Biomedical Problem KU-1, "Spray-On Electrodes." In this application the electrodes were used for EKG monitoring. Additional information on the technique has been obtained from Mr. Clinton Johnson, NASA Flight Research Center, Edwards, California. The dry electrode technique has, in addition, been applied to the monitoring of EMG signals by the Research Triangle Institute's Biomedical Application Team in connection with Biomedical Problem UNC-48, "An Improved EMG Electrode for Hand Therapy".

Benefits to be Derived from Transfer:

The "paint-on" electrodes permit:

1. Maintenance of a precise position on the muscle so that the same muscle fibers are under observation during testing.

2. Maintenance of constant electrode pressure throughout the test procedure.

3. One-man operation so that one of the two therapists previously required can be freed to treat other patients.

The "paint-on" electrode has solved the major difficulties that therapists encounter in administering chronaxie and strength-duration testing to aid in the diagnosis of peripheral nerve lesions. The "paint-on" electrode is in regular clinical use at the Hand Rehabilitation Center.

3.0 PROBLEM STATUS SUMMARY

Problems which are being investigated by the RTI Biomedical Application Team are generally classified as active or closed. Active problems are further subdivided according to the progress or phase of the investigation. Problems are generally closed when either a technology transfer is accomplished or it is judged that further investigation is not likely to produce useful results in a reasonable time. Closed problems are coded according to specific reasons for such action. This section contains a complete summary and analysis of problems which were active at the end of this reporting period and problems which were closed during the reporting period.

3.1 Active Problems

3.1.1 Active Problem Categories

The term "active" means that the problem is still under consideration and that solutions are being sought either on a regular review or a continuing investigative basis. It is implicit in the following discussion that the problems are considered to have a sufficiently high probability of solution as to warrant further activities.

In the Active Problem Summary, Table 7, active problems are divided into the following six status categories:

A. Problem Definition

> Problem definition includes the identification of specific technology-related problems through discussions with biomedical investigators and the preparation of functional discriptions of problems using nondisciplinary terminology.

B. Information Searching

Information relevant to a solution is being sought by computer and/or manual information searching.

C. Problem Abstract Dissemination

An information search has revealed no potential solutions, and a problem abstract is being circulated to individual scientists and engineers at NASA centers and contractor facilities to solicit suggestions.

D. Evaluation

Potentially useful information or technology has been identified and is being evaluated by the team and/or the problem originator.

E. Potential Transfer

Information or technology has been evaluated and found to be of potential value but has not been applied.

F. Follow-up Activity

A technology transfer has been accomplished, but further activity (i.e., documentation, obtaining experimental validation of utility, continuing modification, etc.) is required.

3.1.2 Active Problem Summary Data

The status of all active problems is presented in Table 7. The information included in this table gives problem number and title, date accepted, and a status code for the six categories defined in the preceding section.

Table 7. Active Problem Summary.

(Part of Sec. 3.1.2)

Problem Number	Problem Title	Status	Date Accepted
DU-31	Catheter-Mounted Pressure Transducer.	B	12-67
DU-36	Cervical Cancer Diagnosis.	B	7-68
DU-40	Differential Pressure Transducer for Cardiac Catheter.	F	11-68
DU-41	Electrode Vest for EKG Measurement.	E	1-69
DU-45	Low-Velocity Anemometry.	D	2-69
DU-46	Electrode Material for Pacemakers.	C	3-69
DU-47	Urethral Pressure Transducer.	B	4-69
DU-48	Urine Flowmeter.	D	4-69
DU-49	Electromyography of the Urethra	D	4-69
DU-50	Deep Diving Breathing Systems.	D	4-69
IRM-1	Determination of Brace Socket Pressure.	B	4-69
IRM-2	A Body Power Energy Storage System.	B	4-69
IRM-3	An Improved Spiral Brace.	B	4-69
IRM-4	An Improved Material for Construction of Self-Adjusting Braces.	B	4-69
IRM-5	An Improved Flexible Lead Wire for Implantable Devices.	B	4-69
IRM-6	An Improved Encapsulant for Implantable Devices.	B	4-69
IRM-7	A Material for Use in Direct Contact with Blood Which Exhibits Reduced Clotting Characteristics.	B	4-69
IRM-8	Low Temperature Lubricant for Microtomes.	B	5-69

Table 7. (continued) Active Problem Summary.

Problem Number	Problem Title	Status	Date Accepted
IRM-9	Information on Normal Blood Pressure and Blood Flow in Large Populations.	B	5-69
MISC-2	Fast X-ray for Field Hospital.	D	2-69
NCSU-6	Analysis Techniques for EEG Data.	D	3-69
NCSU-7	Telemetry System for EEG Data.	D	3-69
UNC-38	Electromyography as an Aid to Hand Rehabilitation.	E	2-68
UNC-42	A Means to Collect Exhaled Breath.	B	6-68
UNC-47	An Improved Splinting Material.	D	1-69
UNC-48	An Improved EMG Electrode for Hand Therapy.	F	2-69
UNC-49	A Manipulator for Therapy in Abductor Transfer Cases.	F	2-69
UNC-50	General Purpose, Indicating,Pressure Sensitive Muscle Trainer.	B	2-69
UNC-51	An Improved Electrode for Electro-Diagnosis.	F	4-69
UNC-53	Design Information Relating To Cardiotachometer Circuitry.	D	5-69
UNCD-1	A Method of Producing Silver-Copper and Silver-Tin Alloys in Powder Form with Spherical Shape and with Particle Sizes in the Range of 2 to 4 and 6 to 10 Microns.	B	4-67
UNCD-3	A Means to Obtain Rapidly a Pictorial Representation of the Temperature Distribution of the Interior of the Oral Cavity in Humans.	B	4-67
UNCD-5	An Improved and Reliable Electric Tooth Pulp Tester.	B	5-67
UNCD-6	A Small Sensor to Measure Viability of Human Teeth.	B	5-67
UNCD-15	A Device to Measure Looseness of Teeth.	B	5-68

Table 7. (continued) Active Problem Summary

Problem Number	Problem Title	Status	Date Accepted
UNCD-16	A Sensor to Measure Stress Distribution in Bone as A Result of Applied Force.	B	5-68
UNCD-17	A Method of Measuring Tongue-Lip Pressures on the Teeth.	B	5-68
UNCD-18	Method of Determining if Tooth Roots are Attached to the Jaw Bone Structure.	B	5-68
UNCD-19	A Means of Applying an Electric Field to the Root of the Tooth in Order to Stimulate Bone Resorption.	B	5-68
UNCD-20	A Means of Applying Force to Teeth so that Orthodontic Correction in the Position of the Teeth Can be Achieved.	B	5-68
UNCD-21	A Method of Measuring the Relative Displacement of Teeth With Respect to Some Fixed Point.	B	5-68
UNCD-22	A Method of Measuring the Force Applied to a Tooth by an Orthodontic Structure.	B	5-68
UNCD-23	An Improved Metal with Low Corrosion Rate and High Elastic Modulus for Orthodontic Fixtures.	B	5-68
UNCD-24	Adhesive for Attaching Brackets to Teeth	B	5-68
UNCD-25	A Miniaturized Electrical System to Shock the Tongue of Patients When it is Pressed Against the Rear of their Teeth.	B	5-68
UNCD-26	A Method of Measuring the Height of Bone with Respect to the Teeth in the Jaw-Bone Structure.	B	5-68
UNCD-27	A Method of Maintaining a Thin Tissue Section in Exact Position with Respect to an X-ray Film Plate for an Indefinite Period Even During Development of the Film.	B	5-68
WF-3	Prosthetic Valve for Urinary Tract.	F	8-66
WF-13	Radiation Detector for In Vivo Measurement of Absorbed Dose.	F	10-66

Table 7. (continued) Active Problem Summary.

Problem Number	Problem Title	Status	Date Accepted
WF-24	Respirator Control System that Adjusts Both Volume and Rate as Well as Other Parameters According to Body Needs Determined by Monitoring Continuously the Partial Pressures of Gases in the Blood Stream.	B	5-67
WF-28	A Method of Mixing Indicator with Blood as It is Injected Into Veins and Arteries and a Method of Mixing Again Just Before the Sampling Site.	B	9-67
WF-29	An Electrode for Measuring Hydrogen Ion Concentration and CO_2 Partial Pressure in the Blood is Needed.	B	12-67
WF-30	An Improved Blood Vessel Constrictor.	F	12-67
WF-31	A Servo-Controlled System to Measure pO_2 and pCO_2 in Expired Gases and to Control the Operation of Respirators.	B	12-67
WF-32	Oxygen Toxicity Effects.	D	12-67
WF-33	Biotelemetry Units.	D	12-67
WF-36	Implantable Pressure Sensor and Telemetry Unit for Measurement of Fluid Pressure in the Cranial Cavity.	D	1-68
WF-37	An Implantable Valve Which Can be Remotely Opened and Closed from Outside the Body.	F	1-68
WF-38	An Inexpensive Sterile Fabric for Sheets, Operating Room Gowns, Tissue Transfer, etc.	B	1-68
WF-40	Localization of Blood Pools in Various Cavities of the Body.	D	2-68
WF-41	Low Cost, Swallowable, Temperature-Sensing Telemetry Capsule.	D	2-68
WF-42	Ventilators for Small Animals.	B	2-68
WF-44	A Means of Reducing Dose Rate While Taking X-ray Cineradiographs.	D	2-68

Table 7. (continued) Active Problem Summary .

Problem Number	Problem Title	Status	Date Accepted
WF-46	An Artificial Hand With Touch and Prehension Pressure Feedback to the Human Operator.	B	3-68
WF-47	Information on Techniques and Advances in Thermography.	D	3-68
WF-48	Information on Cardiovascular Systems.	D	3-68
WF-50	Application of Time-Series Analysis to Computer Processing of Biomedical Data.	F	4-68
WF-52	Methods of Triggering from a Fixed Reference Point on the EKG Waveform.	F	5-68
WF-53	Means of Obtaining the Velocity Spectrum of Blood Flowing in Arteries and Veins.	B	5-68
WF-54	An Improved Sensing System for Indicator Dilution Studies.	F	6-68
WF-55	A Simple Means of Sensing Whether Respirator is Actually Performing the Respiratory Function on Humans.	F	6-68
WF-56	An Improved Fluid Pressure Calibration System.	B&D	6-68
WF-59	Noninvasive Means of Detecting the "Bends" in Humans During and Following Decompression.	D	8-68
WF-61	An Improved Method of Determining Volume Elasticity of Blood Vessels.	B	9-68
WF-62	An Extremely Thin Pressure Transducer to Measure the Pressure Exerted on Tissue by Support-Type Hosiery.	D	11-68
WF-63	A Low Cost, Swallowable, pH Sensing Telemetering Capsule.	F	12-68
WF-64	Improved Method of Making Volume Plethysmographic Measurements Related to Volume Changes in Tissue Caused by Influx and Efflux of Blood During the Cardiac Cycle.	B	1-69
WF-65	Function Multipliers to Compute Derivable Physiological Parameters.	B	3-69

Table 7. (Concluded) Active Problem Summary.

Problem Number	Problem Title	Status	Date Accepted
WF-66	An Analog Computer with Interchangeable Problem Boards.	B	3-69
WF-67	A Filter to Separate Physiologic Data Occurring at Nominal Heart Rates from Lower Frequency Data.	B	3-69

3.1.3 Analysis of Active Problem Summary Data

The status of presently active problems are further summarized in Table 8 as to the numbers of problems, the percentage of the total number of active problems in each category, and the average number of months that the problems in each category have been active. These data are useful in evaluating the present status of the RTI Biomedical Application Team Program and indicate where action should be taken to enhance the effectiveness of this effort.

Generally, the data indicate that the major part of the program at present is being devoted to computer and manual information searches, evaluations of information obtained from searches, and follow-up activity related to technology transfers which have already been accomplished. They further indicate a very low level of problem abstract activity. It has been pointed out in previous quarterly progress reports that it is difficult to maintain close contact with medical investigators at universities during the summer months. Thus, the low number of potential transfers reflects the fact that the application team has phased its activities such that a significant part of its effort during the summer months can be devoted to information searching and to evaluation of search results as opposed to evaluating potential transfers which requires close continuing contact with the medical investigator.

Finally, consider the average number of months that problems in each of the categories have been active. In particular, note that cases in the search category have been active somewhat longer than those cases which have proceeded to the evaluation stage. This is an indication that the screening process at the search level is possibly not as effective as it should be. By screening process is meant the routine review of all active problems to determine if the problem should remain active or should be closed. The excessive period of time for which some problems remain in the search category is an indication of the need for improved criteria for closing problems and/or a more objective application of such criteria during problem reviews. These criteria,which are discussed in Section 3.2, of this report are continually being modified to improve the effectiveness and efficiency of NASA's Biomedical Application Team Program.

Table 8

Active Problem Summary Data.

Category	Number of Problems	Percentage	Average Number of Months Active
A. Definition	0	0	-
B. Search	45	56.3	11.3
C. Abstract	1	1.2	3.0
D. Evaluation	19	23.8	9.2
E. Potential Transfer	2	2.4	5.0
F. Follow-up	13	16.3	14.4
All Active Problems	80	100.	10.9

3.2 Closed Problems

3.2.1 Criteria for Closing Problems

A periodic review is conducted of all problems in order to eliminate those problems which are no longer considered to be active. Problems are closed when a technology transfer has been accomplished and also when it is judged that a solution cannot be found and/or applied in a reasonable time.

Reasons for closing the problems are divided into the following categories:

A --- Transfer accomplished.

B --- Researcher has no further interest in the problem.

C --- Researcher has found his own solution.

D --- As a result of personnel transfer in the medical institutions, the problem has either been closed or transferred to another institution along with the investigator and has been given a new number.

E --- No present or foreseeable future NASA technology applicable.

H --- Satisfactory solution identified by team and verified by researcher but transfer cannot be completed by researcher for reasons of economy or lack of resources.

I --- Problem as originally stated was too broad or general.

J --- Problem is too difficult; i.e., the problem as given to the RTI Biomedical Application Team is presently the focus of large expenditures of money,research,and development effort making the likelihood of success by the Biomedical Application Team low.

K --- Problem priority too low. Factors involved are cost/benefit ratio, team resources available, researcher's resources and enthusiasm, etc. compared to these aspects on other problems is too low.

These categories were evolved as a result of interaction between all three Biomedical Application Teams and members of the Biological Sciences Communication Project at George Washington University.

3.2.2 Summary of Closed Problems

Table 9 contains those problems which were closed during the reporting period of 15 June 1968 to 14 June 1969. Table 10 contains those problems which were closed during the period from 15 June 1967 to 14 June 1968. No problems were closed prior to June of 1967.

3.2.3 Analysis of Closed Problem Summary Data

In order to facilitate an analysis of the data contained in Tables 9 and 10, these data have been further summarized and are presented in Table 11. Table 11 presents the numbers of problems closed, the percentages of problems closed, and the time these problems remained active for each of the nine categories for which problems can be closed. The data contained in this table represent all closed problems for the period 15 June 1967 to 14 June 1969. Data for each of the two years represented here are available on an individual yearly basis. An attempt has been made to compare these data for each of the two time periods. A comparison of the effectiveness of our problem review or screening process was not possible because a significantly increased attention to problem review and screening was effective during the second of these two years. Additionally, the criteria for closing problems has been changed during

Table 9. Closed Problem Summary June 15, 1968 to June 14, 1969

Problem Number	Problem Title	Reason Closed	Date Accepted	Date Closed
DU-1	Techniques for Calculating Left Ventricular Volume from Biplane Cine-radiographs.	A	7-66	3-24-69
DU-7	Microforce Transducer.	B	10-66	11-68
DU-8	Methods of Studying Quantitatively Diseased Membranes in Different Joints of the Body.	H	12-66	3-24-69
DU-9	A 4-Channel Telemetry System to be Used in Experiments with Dogs.	B	12-66	3-24-69
DU-11	Pressure Transducers for Intracavitary or Subcutaneous Implantation in the Body.	B	1-67	3-24-69
DU-16	Visual Discrimination in Photos and X-ray Pictures.	H	2-67	3-24-69
DU-20	Multielectrode Needles.	A	3-67	3-24-69
DU-21	Method of Measuring Radial Component of Ionic Current Flow Through Nerve Membrane.	I	4-67	3-24-69
DU-23	Methods of Improving Resolution and General Quality of Electron Micro-graphs to Obtain More Information on the Structure of Cell Membranes.	A	4-67	3-24-69
DU-26	Cardiac Artery Constrictor.	B	6-67	9-30-68
DU-29	Methods of Fabricating Sucrose Gap-etching.	A	9-67	3-24-69
DU-30	Technique for Heparinizing Catheters.	B	9-67	11-68
DU-32	Resolution Improvements in Ultrasonic Holography by Analytical Methods.	I	5-68	3-24-69
DU-33	Fabrication Source for Special Purpose Catheter to be Used in Left Heart Bypass.	B	5-68	11-68
DU-34	Electronic Control and Synchronization System for Left Heart Bypass Pump	B	5-68	11-68

Table 9. (continued) Closed Problem Summary June 15, 1968 to June 14, 1969

Problem Number	Problem Title	Reason Closed	Date Accepted	Date Closed
DU-35	Information on Use of Digital Image Processing for Plotting Trajectories Of Positions of Heart Wall Throughout Cardiac Cycle.	B	5-68	5-22-69
DU-37	Localized Cooling of Heart Muscle.	A	7-68	3-69
DU-38	Analysis of Electrophoretic Patterns of Serum.	B	11-68	4-21-69
DU-39	Miniature Pediatric Pulse and Breathing Rate Monitor.	H	11-68	4-29-69
DU-42	Avian Aerodynamics.	H	2-69	4-22-69
DU-43	Small Low-Velocity Flight Balance.	A	2-69	5-20-69
DU-44	Reflectance Spectrum of Snail Shells.	B	2-69	5-1-69
HSS-1	A Method of Measuring and Telemetering the Force Applied to Broken Bone Joints by Implanted Braces.	A	3-67	12-68
HSS-2	A Method for Measuring and Telemetering Pressures on the Surface of Prosthetic Hip Joints.	B	3-67	12-68
MISC-1	Biomedical Tape Recorder.	A	1-69	3-24-69
NCSU-1	The Application of Mathematical Modeling Techniques to the Cardiovascular System.	E	2-68	12-4-68
NCSU-2	Information on Environmental Capsules for Opossums.	A	5-68	9-30-68
NCSU-3	Information on Timing and Frequency Characteristics of the Heart.	B	7-68	4-9-69
NCSU-4	Telemetry from Wood Ducks in Natural Environment.	A	11-68	5-20-69
NCSU-5	Oxygen Content of Ichthyological Ovarian Fluid.	A	11-68	3-69
RU-1	A Survey of Computer Techniques for Analyzing Physiological Data.	I	3-67	12-68

Table 9. (continued) Closed Problem Summary June 15, 1968 to June 14, 1969

Problem Number	Problem Title	Reason Closed	Date Accepted	Date Closed
RU-2	A Survey of Recently Developed Transducers for Monitoring Physiological Parameters.	I	3-67	12-68
MFH-2	Catheter-Mounted Flow in Pressure Transducers.	I	5-67	12-68
UNC-2	Data on Physiological Calcium Loss in Weightless Environments Which May be Relevant to Understanding Mechanisms of Bone Growth and Resorption in the Human Body.	A	8-66	9-30-68
UNC-7	Determination of Radiation Dose as Function of Position of Radioactive Needles or Wires in Body.	B	11-66	5-20-69
UNC-10	A Portable, Lightweight, and Inexpensive EKG Tape Recorder.	B	11-66	4-2-69
UNC-11	A Semiportable Instrument for Measuring Blood Pressure Which is Not Subject to Operator Error.	B	11-66	4-2-69
UNC-12	Low Temperature Lubricant for Microtomes.	A	12-66	9-30-68
UNC-14	Techniques for Soldering Aluminum.	I	12-66	7-9-68
UNC-15	Method of Quickly and Accurately Measuring the Angles Which Each Finger Segment Makes with Adjacent Segments.	B	12-66	4-2-69
UNC-16	Technique for Identifying all the Amino Acids in Urine Quickly.	C	1-67	4-2-69
UNC-17	Better Materials for Microtome Knives Than the Presently Available Steel or Glass.	B	1-67	4-2-69
UNC-18	Method for Cooling a Few mm^3 Tissue Specimen from Body Temperature to $-80^{\circ}C$ in a Few Milliseconds.	E	1-67	4-2-69
UNC-21	Simple Techniques for Telemetering Blood Pressures.	B	2-67	5-20-69
UNC-22	Methods to Identify Quickly What a Drug Intoxicated Person has Ingested as Soon as He is Admitted to the Emergency Ward.	E	2-67	4-2-69

Table 9. (continued) Closed Problem Summary June 15, 1968 to June 14, 1969

Problem Number	Problem Title	Reason Closed	Date Accepted	Date Closed
UNC-23	Implantable Plastic Materials.	B	2-67	5-20-69
UNC-25	Methods for Detecting (Screening) Skeletal or Striated Muscle Relaxants.	D	3-67	4-2-69
UNC-26	Better Assay Methods, Other than Bioassay, for Succinyl Dicholine at the Microgram per Milliliter Level in Serum.	D	3-67	4-2-69
UND-27	Methods for Assay of Succinyl Monocholine in Serum.	D	3-67	4-2-69
UNC-29	Techniques for Maintaining Blood Sugar at a Constant Level Over a Period of Several Hours.	E	3-67	4-2-69
UNC-30	What Parameters Other Than Blood Sugar and Fatty Acid Levels Can Be Used to Follow Utilization of Insulin.	E	3-67	4-2-69
UNC-31	Techniques for Measuring Metabolic Products of Anesthetics in Breath and Body Fluids.	D	3-67	4-2-69
UNC-33	Techniques for Recording or Telemetering Heart Rate, Blood Pressure, and Respiration of Swimming and Diving Animals	B	5-67	5-20-69
UNC-34	A Device for Warming Blood.	H	6-67	4-2-69
UNC-35	A New Device for Measuring Carbon Dioxide in Expired Gases.	B	7-67	4-2-69
UNC-36	A Device to Measure Breath Volume of Patients on Operating Tables.	E	12-67	4-2-69
UNC-37	Prevention of Orthostatic Hypotension.	B	12-67	4-2-69
UNC-39	Recording and Quantification of Electromyographic Signals.	B	3-68	5-23-69
UNC-40	Instrumentation for Infant Behavior.	B	4-68	3-69
UNC-41	Material for and Fabrication of Vasectomy Clip.	B	5-68	1-13-69

Table 9. (continued) Closed Problem Summary June 15, 1968 to June 14, 1969

Problem Number	Problem Title	Reason Closed	Date Accepted	Date Closed
UNC-43	Instrumentation for Automatic Read-Out of Tissue Temperature as a Function of Time and Distance from a Probe Maintained at -40°C.	B	6-68	1-13-69
UNC-44	Investigation of Uterine Cavity Dynamics.	B	7-68	3-69
UNC-45	Investigation of Follicular Rupture.	B	7-68	3-69
UNC-46	Investigation of Utero-Ovarian Communication.	B	7-68	3-69
UNCD-11	A Means of Sampling Bacteria in the Nasal and Sinus Cavities.	A	12-67	11-68
UNCD-12	A Pressure Transducer of Small Size to Measure Air Pressure in the Sub-Glottal Region.	C	12-67	4-23-69
WF-6	Seven-channel, Portable, Battery-Operated Tape Recorder.	A	9-66	5-22-69
WF-20	A Technique for Continuously Monitoring the Inside and Outside Diameter of Capillaries and Small Arteries and Veins.	D	5-67	9-30-68
WF-21	A Method of Measuring Velocities of Individual Red Cells.	D	5-67	9-30-68
WF-23	An Effective Respirator for Infants.	I	5-67	9-30-68
WF-27	An Electrode or Other Type System with Rapid Response to Measure CO_2 Content of Blood in the Brain.	I	8-67	1-24-69
WF-35	Oxygen Tension in Tissue.	B	12-67	5-22-69
WF-39	Information on the Physiological Effects Arising from the Use of Short-Lived Radioisotopes in Treatment and Autoradiography.	A	2-68	9-30-68
WF-43	Means of Defining Driver Tasks for Automotive Drivers.	B	2-68	4-23-69
WF-45	Sensitivity of Animal Cells to Radiation as a Function of Amount of Oxygen Present in Tissue and as a Function of Radiation Dose Rate.	A	2-68	9-30-68

Table 9. (concluded) Closed Problem Summary June 15, 1968 to June 14, 1969

Problem Number	Problem Title	Reason Closed	Date Accepted	Date Closed
WF-49	Information on Sensors, Transducers, and Electronic Circuitry Adaptable to Medical Applications.	B	4-68	4-23-69
WF-51	The Effect of Trace Amounts of Specific Metals on Metabolism.	J	4-68	9-30-68
WF-57	An Improved Miniature Ultrasonic Transducer.	J	6-68	5-23-69
WF-58	Information on Ultrasonics for Proposal.	A	6-68	9-30-68
WF-60	Detecting Abnormality in Vascular Circulation.	D	7-68	1-7-69
VA-1	Improved Techniques for Measuring Blood Flow Continuously.	B	3-67	11-68
VA-3	Transducers Which Can Measure Blood Pressure and Are External to the Body.	B	4-67	11-68
DU-27	A System for Recording and Performing Simple Data Processing of Evoked Action Potential in Smooth Muscle Tissue.	B	6-67	3-24-69

Table 10. Closed Problem Summary June 15, 1967 to June 14, 1968

Problem Number	Problem Title	Reason Closed	Date Accepted	Date Closed
AEI-1	Multiple Electrode Implant for Communicating with Brains.	C	5-67	12-67
AEI-2	A Cathode Ray Tube Camera for Ultrasonic Scanning Systems.	B	5-67	12-67
DU-2	Method for Monitoring NAD in Living Brain Tissue.	B	7-66	12-67
DU-3	Disposable Dialyzer.	J	8-66	12-67
DU-4	Measurement of Extremely Small Temperature Changes.	J	10-66	12-67
DU-5	EMG Electrode Assembly for the Soft Palate.	E	10-66	12-67
DU-6	Correction for Latency in Vidicons.	A	11-66	12-67
DU-10	Techniques for Monitoring Heart Rate, Rapid Changes in Blood Pressure and Detecting Arrhythmias Directly and Automatically from Physiological Data.	B	12-66	12-67
DU-12	Techniques for Enhancing Cineradiographs of Kidneys so that the Arterial Network Within the Kidney can be Mapped.	B	1-67	3-68
DU-13	Sources of K-42 Having Very High Specific Activity.	B	1-67	12-67
DU-14	Spray-on Electrodes.	B	2-67	12-67
DU-15	Techniques for Analyzing Carotid Artery Pressure Pulse to Obtain Blood Flow Data.	I	2-67	12-67
DU-17	Storage and Retrieval of Biomedical Text.	I	3-67	12-67
DU-18	Special Purpose, Real Time Data Processing.	C	3-67	12-67
DU-19	Low Cost, Microminiaturized and Reliable Time Multiplexing and Analog-to-Digital Electronic Equipment.	C	3-67	12-67

Table 10.(continued) Closed Problem Summary June 15, 1967 to June 14, 1968

Problem Number	Problem Title	Reason Closed	Date Accepted	Date Closed
DU-22	Method of Alternately Exposing Tissue to Two Separate Monochromatic Light Beams Having Different Wavelengths at a Rate of 5,000cps.	J	4-67	12-67
DU-25	A Signal Conditioning and Multiplexing System for Multiple Electrode EKG Patient Monitoring.	A	5-67	12-67
DU-24	Instrumentation for Obtaining EKG of Developing Chick Embryo Heart.	E	5-67	12-67
DU-28	Fluid Dynamics of Sucrose Gap Chambers.	A	6-67	12-67
MFH-1	Special Materials to be Used in New Hospital Construction.	I	5-67	12-67
UNC-1	Oxygen Measurements in Gas Mixtures.	J	8-66	12-67
UNC-3	The Effects of Drugs Upon Mental and Physical Activity in Space.	E	8-66	12-67
UNC-4	Information on Biological Rhythms Obtained in Aerospace Research Programs.	B	8-66	12-67
UNC-5	Inserting Needles into Veins.	J	8-66	12-67
UNC-6	Implantable Plastic Materials.	I	8-66	3-68
UNC-8	Method of Monitoring Complete Activity of Mice.	B	11-66	12-67
UNC-9	Analysis of Electrophoretic Scan Data.	A	11-66	3-68
UNC-13	Methods of Reinforcing Thermo-plastic Braces and Casts.	A	12-66	3-68
UNC-19	Methods of Sterilizing Dental Instruments in the Clinic or Office--Quickly and Positively--in One or Two Minutes without Heat or Ethylene Oxide.	E	2-67	3-68
UNC-20	Good Micro-methods for Determination of Fatty Acids.	B	2-67	12-67

Table 10. (continued) Closed Problem Summary June 15, 1967 to June 14, 1968

Problem Number	Problem Title	Reason Closed	Date Accepted	Date Closed
UNC-24	Are there Any Oxygen-Sensitive Electrodes in the Micron-Size Range?	I	2-67	12-67
UNC-28	Good Technique for Measuring Free Fatty Acids in Serum.	K	3-67	12-67
UNC-32	Methods for Measuring--Externally--The Extent of Atherosclerosis in a Limb Artery or Aorta.	K	4-67	12-67
UNCD-2	A Method for Sterilizing Dental Instruments.	I	4-67	12-67
UNCD-4	Technique for Determining Mechanical Stability of Teeth.	I	4-67	5-68
UNCD-7	A Method of Obtaining X-ray Films of the Entire Mouth on a Single Film with a Depth of Focus of 1 mm or Less.	J	5-67	12-67
UNCD-8	A Reliable Automatic Processor for Dental X-ray Film.	B	5-67	12-67
UNCD-9	System for Automatic Scanning and Statistical Analysis of Electron and Photomicrographs.	J	5-67	12-67
UNCD-10	Techniques of Applying Thermography to the Mouth.	I	6-67	5-68
UNCD-13	An Economical Dry Heat Sterilization Apparatus.	A	12-67	3-68
UNCD-14	Design of "Clean" Rooms, Especially "Laminar Flow" Rooms.	A	1-68	3-68
VA-2	Implantable Catheters with Outside Diameter Approximately 0.01 inch.	J	3-67	12-67
WF-1	A Technique for Generating an Ultrasonic Noise Spectrum with a Variable and Sharp Low Frequency Cut-off Characteristic.	B	8-66	12-67
WF-2	A Mechanism for Holding Ultrasonic Transducers to the Skull.	C	8-66	12-67
WF-4	Small Aperture Ultrasonic Transducers Having Large Capture Angle.	D	8-66	3-68
WF-5	Method of Photographing Ultrasonic Energy Patterns.	D	9-66	3-68

Table 10. (continued) Closed Problem Summary June 15, 1967 to June 14, 1968

Problem Number	Problem Title	Reason Closed	Date Accepted	Date Closed
WF-7	Method of Correcting for Spherical Aberration in Ultrasonic Holograms.	A	9-66	3-68
WF-8	Techniques for Analyzing and Obtaining all Significant Information Contained in Ultrasonic Echo Pulses.	D	9-66	3-68
WF-9	Materials for Prosthetics.	I	10-66	5-68
WF-10	Theoretical Treatments of Holography Which Discuss Aberrations and Distortions.	A	10-66	3-68
WF-11	Mechanical Joints, Extensions, etc. That Can Be Used in Powered Prosthetics.	I	10-66	12-67
WF-12	Variable Diameter Probe for Electromagnetic Blood Flow Meter.	D	10-66	5-68
WF-14	Spin Resonance Studies of Physiological Tissue Which Has Been Exposed To Radiation.	D	11-66	12-67
WF-15	Information on Damage to Physiological Tissue Exposed to Low Levels of Radiation.	I	1-67	12-67
WF-16	Low Noise Coaxial Cable for Use in Recording Electroencephalograms.	B	1-67	5-68
WF-17	Helmet Containing Electroencephalograph Electrodes.	B	1-67	3-68
WF-18	Techniques for Averaging Evoked Nerve Responses that Are Simpler and Less Expensive than Commercially Available Instruments.	I	3-67	3-68
WF-19	A Method for Stimulating Nerve Tissue from Outside the Body.	B	3-67	5-68
WF-22	Improved Methods for Presenting and Enhancing Autoradiographic Scan Data.	I	5-67	12-67
WF-25	Data Obtained in Ultrasonic Studies of Materials Which May be Relevant To the Understanding of Scattering of Ultrasonic Energy in Physiological Tissue.	D	6-67	12-67

Table 10. (concluded) Closed Problem Summary June 15, 1967 to June 14, 1968

Problem Number	Problem Title	Reason Closed	Date Accepted	Date Closed
WF-26	Power Sources for Operating Prosthetic Appliances.	I	7-67	12-67
WF-34	Fractionation of Gamma Globulin G.	J	12-67	5-68

Table 11

Summary of data in Tables 9 and 10: closed problems (15 June 1967 to 14 June 1969.

CATEGORY	NUMBER OF PROBLEMS CLOSED	PERCENTAGE OF PROBLEMS CLOSED	TIME PROBLEMS WERE ACTIVE (months)
A	28	19.5	11.2
B	48	32.6	15.2
C	6	4.1	14.0
D	13	9.0	18.3
E	10	7.0	19.8
H	5	3.5	16.2
I	22	15.3	13.7
J	11	7.6	8.9
K	2	1.4	8.5
TOTAL	145	100.0	

this period. Many of the problems were active during parts of both years for which these data have been generated.

An analysis of the cumulative data on closed problems is, however, both very interesting and at the same time instructive. Consider first the percentage of problems which have been closed in each of the nine categories. Under Category A, cases which have resulted in a technology transfer are approximately 20 percent of the total number of problems that have been closed and which require absolutely no further action on the part of the Biomedical Application Team. Of the remaining categories, all of which represent activity that has not resulted in a transfer of technology, the most significant reason for closing problems is found under Category B. As pointed out in the preceding, Category B means that the problem originator at the medical institution has, at some point in time following the problem identification phase of our activity, indicated that he is no longer interested in pursuing a solution to the stated problem. Since this represents approximately one-third of the problems which the team has investigated, it is a very significant factor in reducing the potential effectiveness of the Biomedical Application Team Program.

It is recommended that in the future the Biomedical Application Teams place much greater emphasis, in early screening of problems, on this factor. More specifically, it is suggested that problems be accepted for investigation only after it is determined that the medical investigators have themselves devoted considerable time and effort to obtaining solutions to the subject problems or to research projects which are being affected by the subject problems.

The second largest category for closing problems without obtaining a transfer of technology is Category I. Here the difficulty has been that the Biomedical Application Team members have not defined specific technology-related problems. Rather, they have addressed themselves to broader problems which may in fact involve two or more specific technological requirements, and, because of the complexity of the stated problem, it has not been possible to conduct effective computer information searches or to communicate effectively the requirements to individual engineers and scientists at NASA Research Centers. This is an area where the teams have complete control, and by careful attention to problem identification and specification there should be no further incidences of problems being closed under Category I. Although the remaining seven categories for closing problems represent individually less than 10 percent of the total, they cumulatively represent approximately 35 percent of all problems which have been closed. This indicates clearly that an increased emphasis on problem reviews and screening in general is required.

Consider next the period of time for which problems were active before being closed under one of the nine categories. These data indicate that the team has devoted considerably more time (with the exception of Categories J and K) to unsuccessful problems than it has devoted to successful problems. This fact simply reinforces the conclusion that much greater emphasis must be placed upon problem reviews and screening.

As a final observation note that only seven percent of the problems closed were closed specifically for the reason that no aerospace-generated technology could be identified as a potential solution for the subject problems. This does not indicate that solutions were found in aerospace-generated technology for 93 percent of the problems. It does indicate however that inability to identify technological solutions to problems has not been the major factor in reducing the effectiveness of the Biomedical Application Team Program.

4.0 SUMMARY OF COMPUTER SEARCH ACTIVITIES

4.1 Introduction

The major source of information for the Biomedical Application Team Program is the computer search of NASA's Aerospace Information Bank. This information bank presently consists of approximately 600,000 reports, articles, books, and conference papers dating from 1962 and covering all fields of interest to aerospace engineers and scientists. Abstracts of these documents are published in the Scientific and Technical Aerospace Reports (STAR; N-documents) and the International Aerospace Abstracts (IAA; A-documents). For computer searching of this information bank, these abstracts are stored on magnetic tape and are computer searched using logical combinations of any of approximately 15,000 index terms or descriptors. Information searches are performed for the RTI Biomedical Application Team by the North Carolina Science and Technology Research Center, one of six NASA Regional Dissemination Centers. Search strategies are formulated jointly by members of the Biomedical Application Team and applications engineers at the Science and Technology Research Center. Initial screening of the results of the search is performed at the Science and Technology Research Center,and more detailed analysis and evaluation is performed by members of the Biomedical Application Team.

4.2 Summary of Computer Search Evaluations

Because of the importance of the computer search in the technology transfer process, detailed records of the results of these searches and evaluations of these results are maintained in order that the effectiveness of this resource can be assessed and the search procedure can be modified when such modification is indicated. A summary of these data for 24 computer searches performed during the preceding 12 months is presented in Table 12.

4.3 Analysis of Computer Information Search Data

Of the 24 computer searches summarized in Table 12, action has been completed on 18. Of these 18, documents relevant to the subject problem were requested by the problem originator on 10 problems. That is, approximately 50 percent of computer searches completed during the preceding year have produced results which are potentially useful.

Consider the characteristics of a typical computer information search. Here a typical search will be defined as an average search using the data in Table 12. The characteristics are the following:

Time - Search Initiated to Search Received	1 week
Time - Search Received to Documents Ordered	4 weeks
Number of Hits	74
Number of Documents Requested	9.7
Number of A-numbered Documents Requested	3.6 or 37.2%
Number of N-numbered Documents Requested	6.1 or 62.8%

It should be noted that the average number of documents requested is not an average of those documents requested in all 24 searches in Table 12 but only of the 10 completed searches for which documents were in fact requested. The other data pertained to all 24 searches.

Table 12. Tabulation of Computer Search Evaluation Report Data

Search #	Time (weeks) Search Initiated to Search Received	Time (weeks) Search Received to Documents Requested	#Hits	# Documents Requested	#A Documents Requested	#N Documents Requested	Documents' Relevance to Problem	Transfer
1349	1	8	52	20	6	14	Good	No
1370	1	5	49	5	3	2	Good	Yes
1469-1	1	4	136	7	1	6	Good	Yes
1609	1	2	56	17	7	10	Good	-
1604	1	1	56	3	1	2	Good	Yes
1595	1	4	53	3	1	2	Poor	Yes
679	1	-	109	6	4	2	Good	Potential
1469-2	1	-	136	3	3	0	Good	Yes
1328	1	7	99	14	3	11	Good	No
1351	1	1	96	19	7	12	Poor	No
1350	1	-	14	0	0	0	Poor	Potential
1341	1	-	164	0	0	0	Poor	No
1358	1	-	93	0	0	0	Poor	Potential
1397	1	-	50	0	0	0	Poor	No
1409	1	-	97	0	0	0	Poor	No
1502	1	-	39	0	0	0	Poor	No

Table 12.

Tabulation of Computer Search Evaluation Report Data (Concluded)

Search #	Time (weeks) Search Initiated to Search Received	Time (weeks) Search Received to Documents Requested	#Hits	# Documents Requested	#A Documents Requested	#N Documents Requested	Documents' Relevance to Problem	Transfer
1503	1	-	52	0	0	0	Poor	No
1673	2	-	18	0	0	0	Poor	No
1706	1	*	58					
1710	1	*	41					
1578	1	*	68					
1702	1	*	20					
1700	1	*	72					
1698	1	*	148					

*Recent Searches - Information not yet complete.

It is interesting to note that the average number of documents requested is approximately 13 percent of the total number of citations in the search bibliography. This indicates that the searches contain a relatively large amount of irrelevant information. This however is not surprising when one considers that the search results in an average of 74 citations out of a total of over one-half million documents.

Of the total number of documents requested, approximately two-thirds are N-numbered documents and one-third are A-numbered documents. The N-numbered documents are published in STAR and are primarily NASA documents and other government reports,and the A-numbered documents are published in IAA and are primarily from scientific journals, books, conferences, and translations of foreign documents. Thus, two-thirds of the requests are for NASA and other government reports. This ratio may be explained partially by the fact that the medical researchers have greater access to the open literature than to government reports.

The average time required to perform a computer search is approximately one week. The average time required for the investigator to evaluate the search bibliography and order documents is four weeks. It is interesting to note that for those cases in which a technology transfer was accomplished the average time required for the researcher to order documents was approximately 3.5 weeks,and when no transfer was accomplished this time was in excess of five weeks. This difference may be due to a greater probability of success when working with an investigator who is very anxious to obtain useful information. On the other hand the investigator may be more anxious to obtain information when the search bibliographies appear to be most relevant to his problem.

5.0 APPLICATION ENGINEERING ACTIVITY

The real benefits of transferring aerospace technology into the field of medicine will not be realized unless the information and technology identified in this transfer program are actually used and applied in research and medical practice. This application in many cases requires significant applications engineering and, frequently, the creation of new commercial products. At the present time the applications engineering required in applying technology identified by the Biomedical Application Teams must be funded by the problem originator through his own research grants and contracts. The application team encourages the initiation of applications engineering when required and assists the researcher in obtaining the necessary engineering services.

The activities of the Biomedical Application Team which are related to applications engineering can be divided into several categories according to the engineering organizations involved. In the following sections each category is discussed separately.

5.1 Local Commercial Engineering Capabilities

Medical investigators generally do not have adequate hardware fabrication facilities or engineering and technical support for fabricating and applying special instrumentation and devices. Usually, the medical researcher is interested in obtaining a single prototype which requires considerable engineering effort but does not involve a large market potential. Thus, industry is usually not interested in funding the development required for building such prototypes. Additionally, the medical investigator does not generally have contact with a number of manufacturing companies. In order to assist the researcher interested in obtaining special research instrumentation and devices, the Biomedical Application Team has contacted a number of relatively small local engineering and manufacturing firms to determine if they are interested in responding to the needs of medical researchers at nearby institutions. In general, these companies have expressed willingness to assist in prototype development when the instrumentation or device falls within their particular area of competence. These companies and their special capabilities are as follows:

Microtronics Corporation, P. O. Box 95, Carrboro, N. C. -- custom electronic instrumentation

Payne and Associates, P. O. Box 12285, Raleigh N. C. -- life jackets, survival equipment

Perry Electronics, P. O. Box 10217, Raleigh, N. C. -- electronic design, printed circuit boards, electronic modules

Carolina Medical Electronics, Inc., 328 27th Street, N. W., Winston-Salem, N. C. -- sensors, electronic equipment

Carolina Narrow Fabric Company, 1036 N. Chestnut Street, P. O. Box 1400, Winston Salem, N. C. -- textile equipment

5.2 Specific Examples of Application Engineering

In the solution of a number of active problems, applications engineering has been involved and is reported in the transfer summaries.

This activity has involved industrial concerns as well as private individuals. Because these activities cover such a broad range, each effort is reported separately in the following:

(1) International Technical Industries, 4631 Scotts Valley Drive, Santa Cruz, California. This company manufactures a small pressure transducer for the aerospace industry that works on the magnetostriction principle. The devices represent a solution to problem DU-40, Differential Pressure Transducer for Cardiac Catheter. The researcher obtained the transducer for measuring blood flow in the heart using the differential pressure method. This was the first time that the transducer has been used in the field of medicine, and certain changes in the transducer were required which were made jointly by International Technical Industries and the researcher.

(2) Frigitronics, 525 Broad Street, Bridgeport, Connecticut. This company was involved in the solution to problem DU-37 concerning the cooling of a small section of heart muscle. This company manufactures cryosurgical tools, but the temperature range of their instruments was below that required in the problem. Interaction between the team and the company produced a design that would meet the researcher's specifications.

(3) Dr. W. W. Cochran, Urbana, Illinois. Dr. Cochran designs and builds equipment for avian research. In response to problem NCSU-4 [6] requiring telemetry tracking equipment for small ducks, a small telemetry unit was designed and built to meet the needs of a researcher at North Carolina State University.

(4) Solid State Radiation, Inc., 2261 S. Carmelina, Los Angeles, California. Solid State Radiation has developed a solid state radiation probe under NASA contract. Although no longer under NASA contract, the company markets a line of solid state radiation probes, most of which are manufactured for use by the Atomic Energy Commission. The probes were identified as representing a solution to problem WF-13, Radiation Detector for In Vivo Measurement of Absorbed Dose. Arrangements were made through the courtesy of Dr. Hodge R. Wasson of the Atomic Energy Commission and Dr. Henry S. Katzenstein, President, Solid State Radiation, Inc., to obtain a radiation probe and associated equipment for trial use in this application. The unit has been in the hands of the researchers for some months during which time extensive calibration procedures have been completed and familiarity has been gained in use of the equipment. In vivo tests in humans are scheduled to begin in the near future.

(5) Biomedical Engineering Department, Bowman Gray School of Medicine, Winston-Salem, North Carolina. The solutions to two problems, WF-3 "Prosthetic Valve for Urinary Tract" and WF-30 "An Improved Blood Vessel Constrictor", have required custom machine shop facilities. The Biomedical Engineering Department at Bowman Gray has a small facility for such work. During this year, design drawings of the two devices have been made as a result of interaction between the Biomedical Application Team and the researchers. The Biomedical Engineering Department has evaluated the designs, made constructive suggestions involving design, and submitted fabrication cost estimates to the researchers.

(6) Private individual assistance. In addition to activities with commercial and university engineering organizations, there has been at least one interaction between the disciplines of engineering and medicine on a less formal basis. A part of the electronic circuitry in the NASA-developed cardiac R-Wave Detector was useful in the solution of Biomedical Problem WF-52, "Methods of Triggering from a Fixed Reference Point on the ECG Waveform." The researcher, Dr. George S. Malindzak, Jr., has obtained the assistance of a personal acquaintance, an electrical engineer, to design and build a simple R-wave trigger unit based on the design philosophy of the NASA-developed unit.

5.3 Application Engineering at the Research Triangle Institute

The Reseach Triangle Institute has facilities and capabilities that have contributed to the solution of a number of problems. These activities are reported in the following paragraphs.

(1) The Institute designed, fabricated, and tested a special purpose amplifier system for recording potentials from a multipolar electrode in the heart. Although this activity was reported in the DU-25 Transfer report [3], significant activity has occurred during the past year on the fabrication and testing of this equipment. In addition, as a result of this initial system, the researcher has contracted with RTI to build a similar system for feeding up to 50 channels of similar information into a digital computer. This new system has been built and is undergoing testing.

(2) The Institute has designed, fabricated, and is in the process of testing a special purpose fiber optic device for use in sensing the concentration of an indicator dye that absorbs light in the infrared. The device is designed to detect the change in dye concentration in blood (into which an indicator dye has been injected) as the blood flows past the fiber optic illuminator and transmitted light pickup.

(3) The Research Triangle Institute has fabricated an electromyographic amplifier using circuit design information supplied by the Hand Rehabilitation Center of the University of North Carolina Medical School. The unit has been fabricated, testing is in progress, and delivery of the unit to the Hand Rehabilitation Center is expected in June 1969.

(4) As reported on problem DU-20 [4], a requirement existed for a needle containing 15 electrodes spaced 1 mm apart. Existing fabrication techniques were inadequate but a significant improvement was suggested by an Institute staff member which was utilized by Duke University researchers. The interaction between these two groups was stimulated by the Biomedical Application Team.

6.0 CONCLUSIONS

This report has summarized the activities of the Research Triangle Institute Biomedical Application Team during the past three years in order to more effectively analyze the methodology. Optimization of the methodology by the experimental and analytical process is necessary to successfully utilize the Biomedical Application Team approach. The conclusions presented below are discussed in detail in the previous sections of this report.

Of all the problems that have been closed, only seven percent have been closed because there was no relevant aerospace technology. This does not imply that 93 percent of the closed problems were technology transfers, but it does point out the fact that lack of technology is not a serious impediment to the program.

The average time for a transfer was 5.25 months, whereas the average problem has been active for 11.3 months. Comparing these figures, one can see that solutions to problems that result in transfers are found rather early as compared with the average time all problems are active. Consequently, it appears that more emphasis should be placed on review of active problems to screen out those which have low probability of solution. Particularly, a problem should receive critical review when it has been active for six months without a transfer.

Generally speaking, the time required to accomplish all the various phases of the transfer process are significantly less for successful transfers than for those problems for which no transfers result. For example, the average time that a researcher takes to order documents is 5.3 weeks for problems that do not result in transfers and 3.5 weeks for problems that do result in transfers. This implies that one improvement in the review and screening process might be to place time limits on the various phases of the transfer process. It is apparent that some flexibility would be necessary in these limits, but, if such limits can be evolved, they may effectively serve as landmarks to indicate when a problem should receive additional activity or further evaluation.

In analyzing the types of documents that have been judged relevant and that have been ordered by researchers, we find that 62.8 percent of the documents ordered were N-numbered documents, which represent government aerospace documents,and 37.2 percent were A-numbered documents,which represent open aerospace literature. Consequently, both are significant document sources and are of importance to the program; however, the N-numbered documents appear more likely to contain information not previously seen by the researcher.

Of the closed problems, 30 percent have been closed because of "no further interest on the part of the researcher" (category 3). Obviously, more emphasis must be placed on problem selection during the problem identification phase. Problem selection/rejection criteria must be applied more judiciously. Additional efforts must be made to determine researcher interest in the problem, as well as his willingness to invest time and effort in seeking and implementing a solution.

As increasing emphasis is placed on problem selection and review, the team will be able to concentrate on those problems most likely to result in transfers. This should increase the transfer-to-active problem ratio. As a corollary, the team will be able to process a larger number of problems, thus permitting an increase in the number of participating investigators and expansion of the program to involve a larger number of participating institutions.

It becomes immediately clear that the increasing emphasis on problem screening and the more vigorous application of the problem rejection/selection criteria will place an even greater importance on the role of the consultant at each participating institution. The consultant is the best aid and the most reliable source of information available to the Biomedical Application Team in identifying researchers and evaluating their interest in and potential response to the program. Consequently, in expanding the base of participating institutions, the choice of the best individuals to serve as consultants will be even more important. The characteristics desirable in a consultant should be developed to permit the proper choices. The following, while certainly not all-inclusive, is a list of desirable characteristics of consultants:

(1) He must be enthusiastic about the Biomedical Application Team Program.

(2) He must be cognizant of the overall research activities of the institution.

(3) His technical and research ability must be recognized and respected within the institution.

(4) A multidisciplinary background with some exposure to electronics, instrumentation, or computers is desirable.

(5) It is desirable that he be actively involved in research projects himself.

(6) He must be able to communicate with people.

Finally, it is clear that the concept of the Biomedical Application Team is a viable one and is one of the most exciting concepts available for bridging the gap between the fields of medicine and aerospace technology. It is recommended that this unique approach be continued as an operational process while continually refining the methodology by the experimental method.

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